

Detectability of cerebral chronic white matter microangiopathy on CT compared to MRI: A teleradiology study

To Cite:

Ajlan AM, Eskander AA, Alhazmi TA, Ibrahim NK, Abduljabbar A, Wazzan M, Khashoggi K, Ahmad R, Elkashty AE. Detectability of cerebral chronic white matter microangiopathy on CT compared to MRI: A teleradiology study. *Medical Science*, 2021, 25(111), 1044-1051

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Peer-Review History

Received: 22 March 2021

Reviewed & Revised: 23/March/2021 to 25/April/2021

Accepted: 26 April 2021

Published: May 2021

Peer-review Method

External peer-review was done through double-blind method.

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ABSTRACT

Background: Cerebral chronic white matter (WM) microangiopathy is common with ageing and vasculopathy. It is known to be better detected on magnetic resonance imaging (MRI) compared to computed tomography (CT). **Objective:** To determine the detectability of WM microangiopathy on CT compared to MRI; utilizing a subjective visual approach. **Material and Methods:** A retrospective chart review was done in a private Jeddah's hospital during 2020/2021. Four months of a local teleradiology practice archive was assessed for patients more than 40 years old who underwent both MRI and CT simultaneously. Those with known acute or other WM non-macroangiopathic findings were excluded. Detectability, size and location of supratentorial chronic WM changes were recorded for MRI and CT, considering MRI as the gold standard. Locations were categorized as periventricular, deep, juxtacortical and combination of all regions. Variable degrees of concordance between MRI and CT were assessed. Statistics were expressed in frequency distributions and mean \pm standard deviation. Comparison of categorical data by Fisher's exact tests and between means by Mann Whitney U non-parametric test were performed (i.e., significant if P -values < 0.05). **Results:** A total of 35 cases were studied (62.9% males; mean age 40 ± 4.6 years). WM changes were present in 77.1% on MRI and 45.7% on CT. MRI WM changes were seen in all WM locations in 34.3% and in a juxtacortical site in 20%. CT WM changes were seen in all WM locations in 20%, and in 8.6% in each of deep and in juxtacortical WM in 8.6% locations. MRI and CT complete concordance were noted in 31.4% of cases. In 20% of cases, MRI changes were more severe. Discordance was partial and 17.1% and complete and 31.4% of cases. Smaller lesions were missed more commonly CT, primarily were located in the juxtacortical region. **Conclusion:** Subjective visual approach for detection of WM microangiopathy is more reliable on MRI compared to CT imaging, despite CT ability in detecting such changes and a reasonable number of cases. The most challenging location to identify chronic WM microangiopathy on CT is juxtacortical, especially with smaller lesions. Such



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knowledge has therapeutic and prognostic applications and serves as the basis for future studies.

Keywords: Chronic white matter microangiopathy, small vessel disease, computed tomography, magnetic resonance imaging, FLAIR

1. INTRODUCTION

White matter (WM) changes identified on magnetic resonance imaging (MRI) are common and heterogeneous (Sarbu et al., 2016). The commonest of white matter changes is related to small vessel alteration due to ageing or compounding vasculopathy risk factors (e.g., diabetes mellitus and hypertension). In such instances, the vascular walls undergo progressive lipid, hyalinizing and atheromatous changes that likely result in chronic ischaemic changes of the WM (Wardlaw et al., 2013). The process is multifactorial and yet to be clearly understood. A typical general term describing this process is chronic white matter microangiopathy. However, other names exist, such as small-vessel disease related to arteriolosclerosis and small vessel chronic ischemia, among other terms (Schmidt et al., 2011).

Chronic WM microangiopathy has been identified in the spectrum of clinical presentations, from asymptomatic patients to those presenting with cognitive, behavioural and motor dysfunction (Okroglic et al., 2013). Thus, identifying chronic WM microangiopathy may have management or prognostic implications (Ay et al., 2008; Curtze et al., 2018; Okroglic et al., 2013; Schmidt et al., 2011). Despite that, and the fact that changes are commonly seen on MRI, the same changes may be absent or difficult to detect on computed tomography (CT), sparking efforts to develop semiquantitative methods for detection and reporting (Chen et al., 2018; Hanning et al., 2019).

Given the significance of identifying chronic WM changes on imaging modalities, since semi-quantitative or quantitative methods may be less standardized or potentially non-practical. A very limited number of studies were conducted on such important issue. So, such study is urgently needed. The study was done to determine the detectability of chronic WM changes on CT compared to MRI, in a simplified qualitative practical format.

2. MATERIAL AND METHODS

Study design and period

A retrospective chart review was conducted in one private hospital in Jeddah. It was done during the period from October 2020 to that of January 2021. The study identified the records of patients who underwent simultaneous brain CT and MRI examinations in the same setting.

Subjects

Subjects data were collected from a local teleradiology practice archiving system after obtaining a research committee ethical approval and waving the informed consent. The data collection and vetting were performed by an independent researcher that was not involved in direct image analysis. Patients younger than 40 years old and those already known for acute or chronic white matter changes other than chronic WM microangiopathy were excluded from the study, regardless of risk factors.

Image Analysis

All CT and MRI acquisitions were obtained according to standard protocols, without intravenous contrast administration. Images were analyzed on Paxera Ultima 360 teleradiology PACS system (Paxera Health Co., USA). Generally, the WM changes assessment was performed in line with a modified Fazekas classification (Fazekas et al., 2002). The evaluation was limited to supratentorial changes. When identified on CT, WM changes were categorized as periventricular (lesions within 2 mm or less from the ependymal surface), juxtacortical (lesions within 2 mm or less from the cortex), deep WM location (all supratentorial lesions other than periventricular or juxtacortical sites), or a mix or combination of the mentioned categories.

Two independent, experienced radiologists separately assessed the CT and MRI images. The detectability of the WM changes on MRI was considered the gold standard. Axial CT images were initially evaluated in brain window (width of 80 and level of 40), with optional window adjustment by the reader for better contrast delineation of normal versus abnormal WM. Fluid attenuated inversion recovery (FLAIR) axial MRI images were evaluated utilizing standard Windows (window of 850 and level of 450), with optional window adjustment by the reader for better contrast delineation of normal versus abnormal WM.

A third independent reader assessed the degree of concordance between CT and MRI findings. In case of discordance, the same independent third reader recorded the WM changes disc on locations and the size of the largest discordant lesion. In the case of concordance, the appearance was categorized as the concordance of the same degree (i.e., complete concordance) or concordance with a more severe appearance on MRI than CT. In case of discordance, the appearance was categorized as partially discordant (i.e., fewer locations of WM changes were seen on CT compared to MRI) or completely discordant (i.e., WM changes seen on MRI but none were seen on CT).

Statistical Analysis

All data were collected on a secure Excel document. Statistical analysis was performed on SPSS software (version 21). Descriptive statistics were done as simple frequency distribution tables for categorical variables, and mean \pm SD for continuous variables. Fisher's exact tests were done for comparing categorical data, and Mann Whitney U non-parametric test was used to compare between 2 means. P values < 0.05 were considered statistically significant.

3. RESULTS

A total of 35 cases were identified during the study period. Results found that 22 (62.9%) were males. Their age ranged from 40-56 years with a mean of 40 ± 4.6 years. MRI WM changes were present in 77.1%, but only seen in 45.7% of CT cases. No abnormalities were detected on CT on any of the normal 23% MRI studies. Table 1 describes the characteristics of WM changes on MRI and CT with regards detectability stratified by imaging modality, location and size. Stratified by location, MRI WM changes were seen in deep WM in 2.9%, juxtacortical WM in 20%, both periventricular and deep WM in 2.9%, both periventricular and juxtacortical WM in 2.9%, both deep and juxtacortical and 14.3%, and at all WM sites in 34.3% of the study population. Stratified by location, CT WM changes were seen in periventricular WM in 2.9%, deep WM in 8.6%, juxtacortical WM in 8.6%, both periventricular and deep WM in 2.9%, both juxtacortical and deep WM in 2.9%, and all WM locations in 20%.

Complete concordance in detecting WM changes on both MRI and CT was noted in 31.4% of cases (figure 1). There were 20% of concordant cases at which changes were more severe on MRI than CT. On the other hand, the discordance was partial in 17.1% and complete in 31.4%. The largest discordant lesion size was 3 mm in 23% and 7 mm in 8.6% of cases. The largest discordant lesion was seen most commonly in the juxtacortical area (28.6% of cases) (figure 2). Table 2 describes the comparison between location and visibility of chronic WM microangiopathic changes on MRI and CT according to gender and age. There was no statistically significant difference between both genders to detect WM changes on either MRI or CT ($P > 0.5$). Lack of WM changes on MRI was encountered more commonly in patients aged ≤ 50 years old (27.8%) compared to those > 50 years old (17.6%). Similarly, lack of WM changes on CT was encountered more commonly in patients aged ≤ 50 years (61.1%) compared to those > 50 years (47.1%). However, no statistically significant difference was illustrated between age groups for the absence of WM changes for neither MRI nor CT.

Table 1 Characteristics of Chronic White Matter Microangiopathy on MRI and CT

Characteristic	Frequency	Percentage (%)
WM Changes on MRI		
None	8	22.9
Present	27	77.1
Location of MRI WM Changes		
None	8	22.9
Deep	1	2.9
Juxtacortical	7	20
Periventricular and Deep	1	2.9
Periventricular and Juxtacortical	1	2.9
Deep and Juxtacortical	5	14.3
All Locations	12	34.3
WM Changes on CT		
None	19	54.3
Present	16	45.7

CT WM location visibility		
None	19	54.3
Periventricular	1	2.9
Deep	3	8.6
Juxtacortical	3	8.6
Periventricular and Deep	1	2.9
Deep and Juxtacortical	1	2.9
All Location	7	20
Concordance in Detecting WM Changes Between MRI and CT		
Fully Concordant	11	31.4
Concordant but More Severe on MRI	7	20.0
Partially Discordant	6	17.1
Completely Discordant	11	31.4
Size of Largest Discordant Lesion (mm)		
None	18	51
2 mm	1	2.9
3 mm	8	23
4 mm	3	8.6
5 mm	1	2.9
6 mm	1	2.9
7 mm	3	8.6
Location of Largest Discordant Lesion		
None	19	54.3
Periventricular	3	8.6
Deep	3	8.6
Juxtacortical	10	28.6

Table 2: Comparison Between Location and Visibility of Chronic White Matter Microangiopathy on MRI and CT According to Gender and Age

<div>Location</div> <div>Variable</div>	None	Deep WM	JC WM	PV and Deep WM	PV and JC WM	Deep and JC WM	All Locations	Total	Fisher's exact test (P)
MRI									
Gender									
Male (Number)	5	1	4	1	1	4	6	22	3.35 (0.76)
%	22.7	4.5	18.2	4.5	4.5	18.2	27.3	100	
Female (Number)	3	0	3.0	0	0	1	6	13	
%	23.1	0	23.1	0	0	7.7	46.2	100.0	
CT									
Male (Number)	12	1	2	1	1	1	4	22	3.01 (0.8)
%	54.5	4.5	9.1	4.5	4.5	4.5	18.2	100	
Female (Number)	7	0	1	2	0	0	3	13	
%	53.8	0	7.7	15.4	0	0	23.1	100	
MRI									
≤ 50 (Number)	5	1	4	0	1	4	3	18	8.42 (0.21)
%	27.8	5.6	22.2	0	5.6	22.2	16.7	100	

> 50	(Number)	3	0	3	1	0	1	9	17	
	%	17.6	0	17.6	5.9	0	5.9	52.9	100	
CT										
≤ 50	(Number)	11	0	1.0	2	0	1	3	18	4.26 (0.64)
	%	61.1	0	5.6	11.1	0	5.6	16.7	100	
> 50	(Number)	8.0	1.0	2.0	1	1	0	4	17	
	%	47.1	5.9	11.8	5.9	5.9	0	23.5	100	

*WM= White matter, PV = Periventricular, JC Juxtacortical

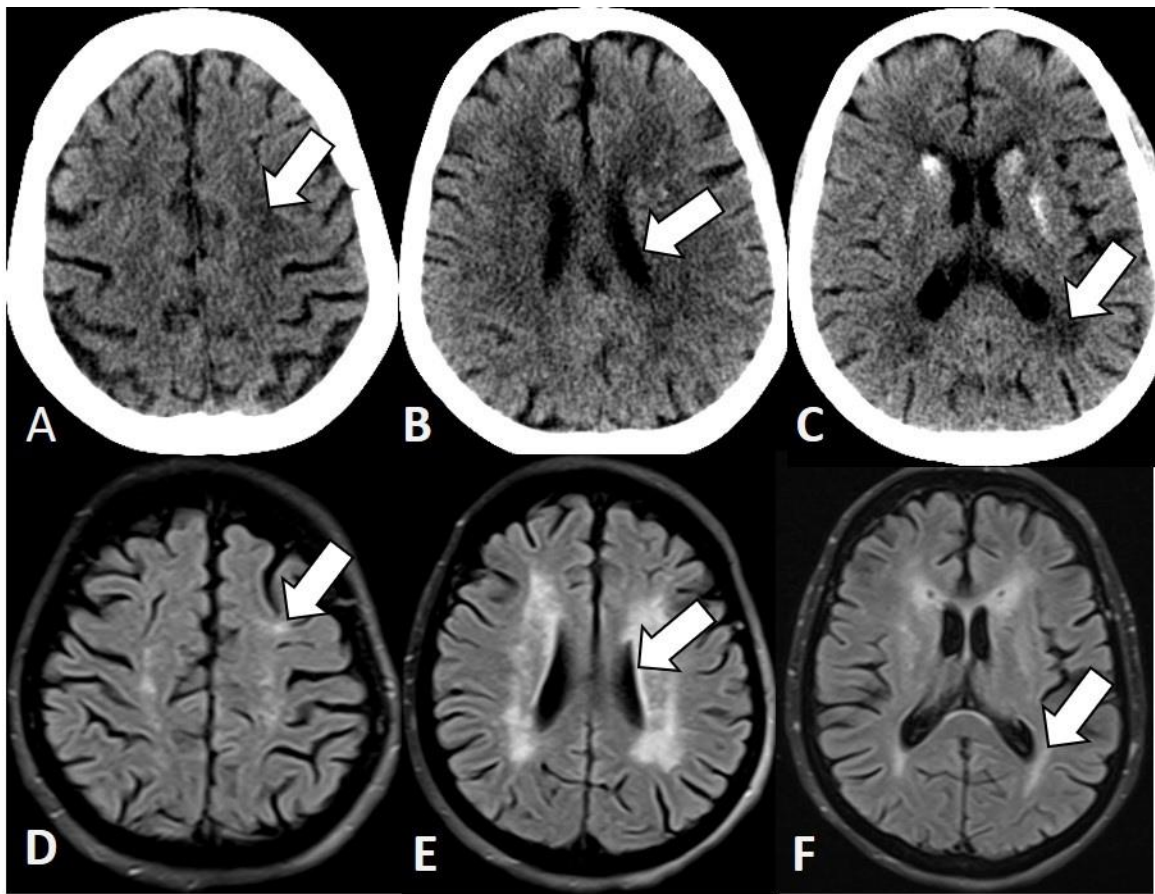


Figure 1 53-year-old male with selected brain images on CT (upper row; images A-C)) and MRI (lower row; images D-E). There is concordant white matter microangiopathy on CT and MRI in juxtacortical (images A and D), periventricular (images B and E) and deep (images C and F) locations.

4. DISCUSSION

The observers detected WM microangiopathy changes in more than two-thirds of the MRI studies and detecting such changes in less than half of the same patient population on CT. Such discrepancy in WM microangiopathy detection is not surprising, given the superior soft-tissue resolution capabilities of MRI (Chen et al., 2018; Fazekas et al., 2002; Hanning et al., 2019). Such shortcoming in CT imaging is significant to highlight, given that the identification of WM microangiopathy has important implications from the clinical standpoint (Ay et al., 2008; Okroglic et al., 2013). From an imaging perspective, prior studies have attempted to address such discrepancy (Chen et al., 2018; Curtze et al., 2018; Hanning et al., 2019). However, these studies had different methodologies, mainly relying on automated or semiautomated assessments. Given that automated detection or grading of WM changes on CT is either not available or not practical within the workload of daily service, we designed our study to be based on subjective visual assessment. So, MRI had a trend to better show the lesions compared to CT. The extent of the abnormality was seen to a larger degree on MRI, and smaller lesions were occasionally missed on CT. Such findings are in line with prior literature.

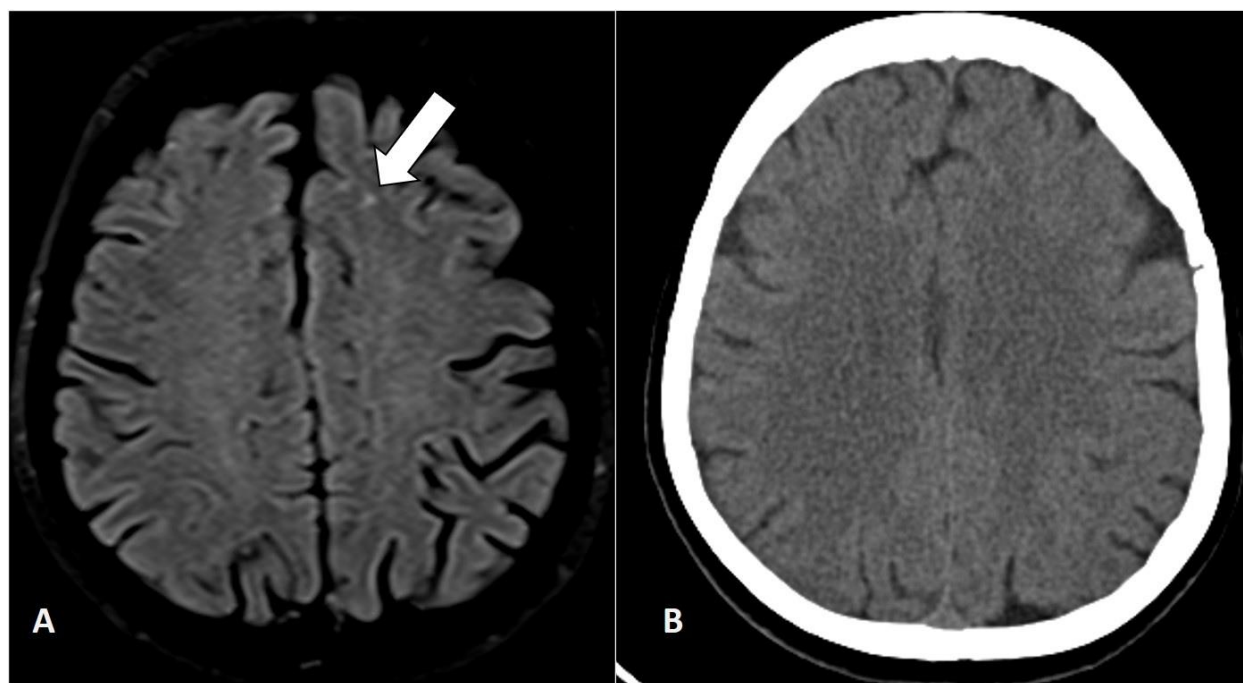


Figure 2 44-year-old male patient with the tiny foci of juxtacortical chronic white matter microangiopathy on MRI (arrow in image A), with the none visualisation on corresponding CT (image B).

When WM changes were noted on MRI, they were most commonly seen in all three locations (i.e., periventricular, deep and juxtacortical regions). The most common site of detecting WM changes on MRI was juxtacortical, seen in isolation or combination with other locations in 71.5% of cases. Despite that, only 31.5% of juxtacortical WM changes were detected on CT. Thus, it appears that juxtacortical WM microangiopathic changes are most difficult to see on CT, compared to periventricular and deep locations. When WM changes were detected on MRI, CT could detect the abnormality with variable degrees of concordance in 68.5% of cases. It is not surprising that the smaller the detected lesions on MRI the more likely such lesions would be missed on CT. Lesions are about 3 mm or most commonly missed on CT imaging compared to MRI. On the other hand, lesions as large as 7 mm were also missed, but were most commonly located in juxtacortical location. This observation further supports our realization mentioned above that juxtacortical WM changes are typically difficult to detect on CT scan.

WM changes were more commonly detected in both males and females in both MRI and CT in patients older than 50 years in age. There was no statistically significant difference between the presence or absence of WM changes in patients ≤ 50 years old versus those > 50 years old. Although our observations are consistent with daily practice, we acknowledge the relatively small study sample. However, the study tackled detectability of WM changes on MRI compared to CT from a different perspective. The methodology was mainly based on a more subjective assessment, which is easier to implement in practice. Furthermore, a teleradiology archive was used to collect the study sample, potentially diversifying the studied population. This approach could be a nucleus for further studies with larger cohorts. Future literature may capitalize on a few other points that this study did not tackle. For example, old lacunar infarcts were not addressed, which is considered part of chronic white matter small vessel disease (Hanning et al., 2019; Okroglic et al., 2013; Sarbu et al., 2016). Another important imaging finding that was not evaluated in this study is acute ischaemic or haemorrhagic infarctions and the correlation of those acute findings with chronic WM microangiopathy.

5. CONCLUSION

Subjective visual detection of WM microangiopathic changes is more reliable on MRI compared to CT imaging. However, CT remains capable of detecting WM changes in a reasonable number of patients compared to MRI. Detectability of WM changes on CT compared to MRI does occur in variable degrees of discordance in severity, size and location. The most challenging site to detect chronic WM microangiopathy on CT is juxtacortical. Knowledge of such facts is essential to consider in a therapeutic and prognostic frame and may serve as a base for future studies.

Abbreviations

White matter (WM),
Magnetic resonance imaging (MRI),
Computed tomography (CT),
Fluid attenuation inversion recovery (FLAIR)

Acknowledgement

We are extremely thankful to all the patient participants and the hospital's officials who were made the study reality. We are also greatfull to the support provided to us by Doctor Randa Alyfeai throughout the study period.

Authors' contributions

Amr M. Ajlan (study concept, methodology, manuscript writing and study supervision), Ayman A. Eskander (data collection, data processing, manuscript revision, and study supervision), Turki A. Alhazmi (data collection, data processing, manuscript revision, and study supervision), Nahla Khamis Ibrahim (statistical analysis, and helped in manuscript writing and revision), Ahmed Abduljabar (data analysis and manuscript revision), Mohammad Wazzan (data analysis and manuscript revision), Khalid Khashoggi (data analysis and manuscript revision), Rani Ahmad (data analysis and manuscript revision), and Ayman Esmaeil Elkashty (logistic support and manuscript revision).

Funding

This study has not received any external fund.

Conflict of Interest

The authors declare that there are no conflicts of interests.

Informed consent

Given the nature of the study, an informed consent has been waived by the research committee of ethical approval.

Ethical approval for study protocol /study design /Methodology

The study was approved by the Diagnostics Elite Committee for Research Ethical Approval (number: DE-EC-002).

Data and materials availability

All data associated with this study are present in the paper.

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